Shared Mobility Benefits Calculator

Methodology

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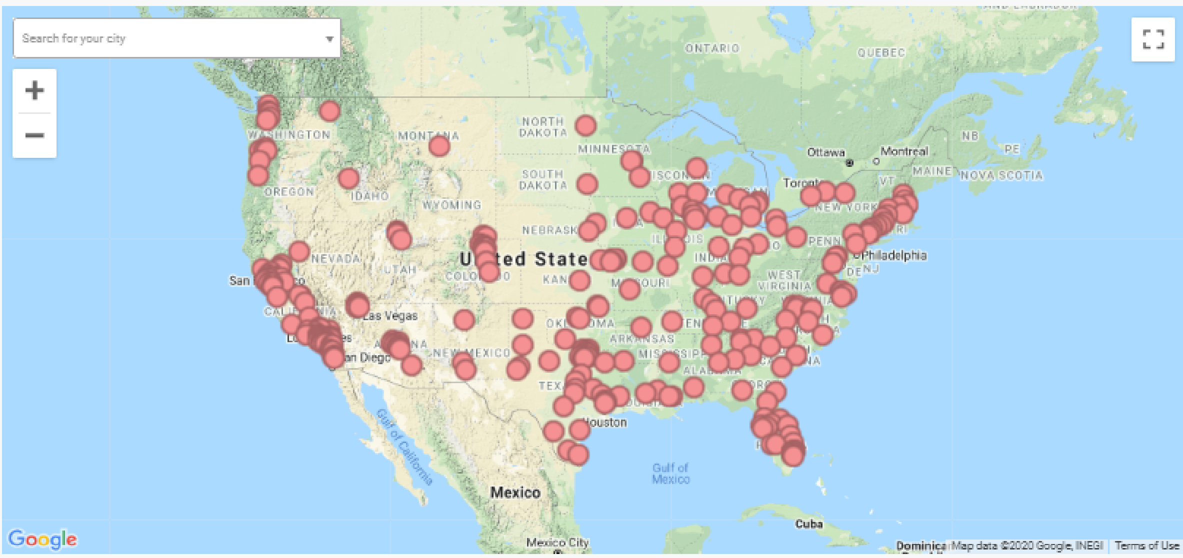
Shared Transportation Modes Dramatically Reduce Greenhouse Gases

The Shared Mobility Benefits Calculator is an aspirational tool for cities to estimate the emissions benefits from deploying various modes of shared mobility. Using these estimates, policymakers can envision and set goals towards reducing congestion, household transportation costs, and carbon emissions from personal vehicles. Although the benefits estimated by SUMC's Calculator are ambitious in nature, the numbers behind the impacts represent real possibilities. These figures are derived from research publications and shared mobility user surveys in the US and other developed nations. By incorporating combinations of these modes into city and regional planning, local governments can turn greenhouse gas mitigation goals into concrete plans. For additional information see [link to learning center method]



Cities can make a huge difference for climate

U.S. Cities with more than 100,000 people are home to **94 million people** who need to get to work, run errands, and have fun. All that mobility right now leads to 264 million tonnes of greenhouse gas emissions every year. But with investments in mass transit, electric vehicles, and innovations in shared mobility, those same cities could **cut their transportation emissions by 84%.**

Just the top 50 cities can change the equation

That will take action by more than 300 cities. But if the **top 50 cities** did all they could to cut emissions through shared mobility, their actions alone could save more than **100 tonnes of greenhouse gas emissions**, every year!

That's 40% of the total transportation emissions across all 300+ U.S. cities with more than 100,000 people.

Access the Shared Mobility Benefits Calculator Here:
https://learn.sharedusemobilitycenter.org/benefitcalculator/

Introduction:

The Shared Mobility Benefits Calculator is a tool for cities to estimate the emissions benefits from deploying various modes of shared mobility. Using these estimates, policymakers can envision and set goals towards reducing congestion, household transportation costs, and carbon emissions from personal vehicles. Although the benefits estimated by this Calculator are ambitious in nature, the numbers behind the impacts represent real possibilities. These figures are derived from research publications and shared mobility user surveys in the US and other developed nations. By incorporating combinations of these modes into city and regional planning, local governments can turn greenhouse gas mitigation goals into concrete plans. Multimodal transportation infrastructure leads to other benefits not quantified here but also of great importance, such as health benefits in living a more active lifestyle, providing first and last mile connections, and providing mobility for those that live in neighborhoods with limited transportation options. In nominal terms, those first/last-mile options (such as bikeshare or shared electric scooters) may show lower impacts compared with similarly-scaled applications of commuting modes such as transit, carpooling, or telecommuting. However, these modes do not operate in a vacuum. First/last-mile connections improve the quality of a transit system and any multi-modal network is strengthened by its diversity of options. While this effect may not be captured in the Shared Mobility Benefits Calculator, it remains important for planners and policy-makers not to rely on any single tool to mitigate transportation related GHG emissions.

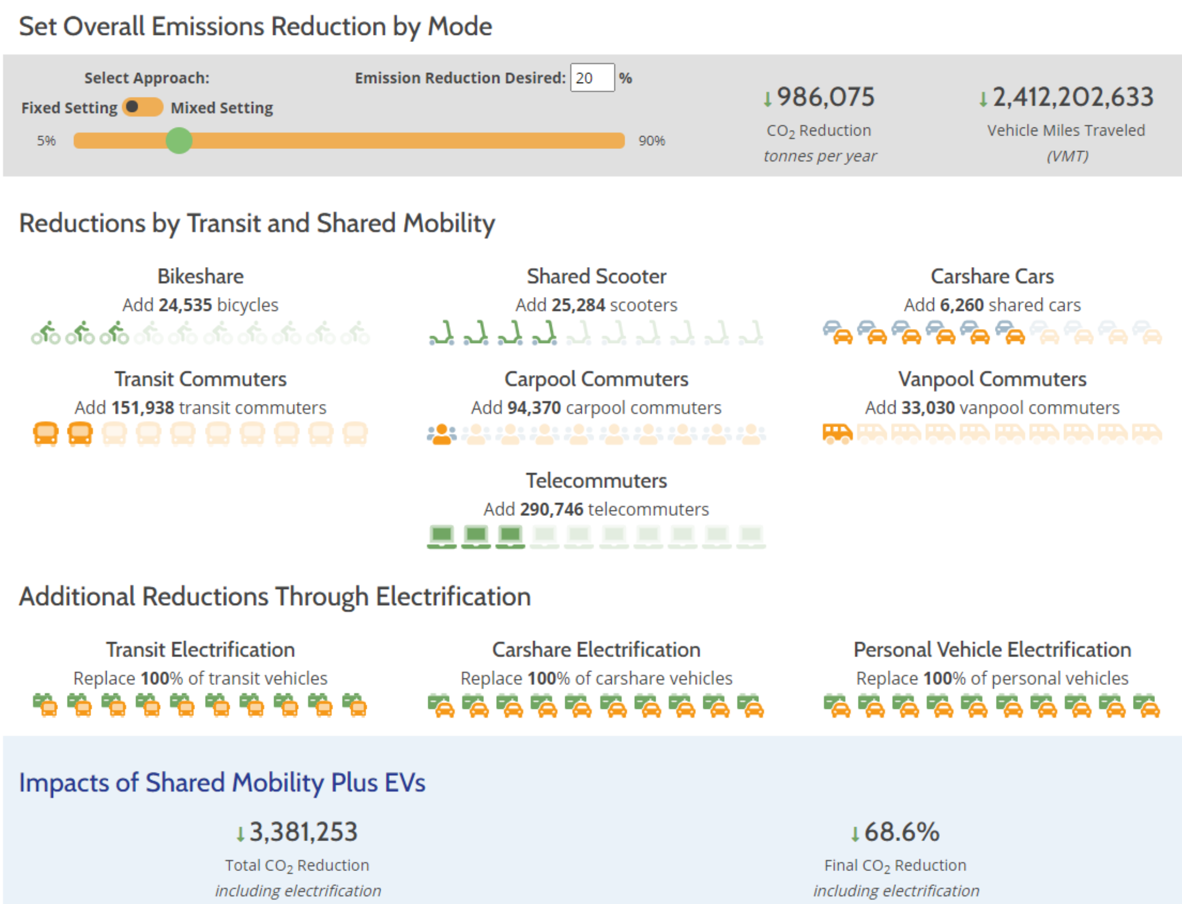
The methods described in this calculator are among many ways that cities can reduce the climate impacts of transportation. Future versions of this calculator may include incentivizing flexible work schedules, congestion pricing, and adjustable parking requirements. This larger set of tools (which also includes telecommuting) generally falls under Transportation Demand Management (TDM). Together, TDM tools and strategies will help cities think through the impacts of personal travel and what solutions are available to help cities reduce transportation related GHG emissions.

It is important to acknowledge the impact of land-use and planning policies on shared mobility. In order for these modes to increase their market share, local governments must create opportunities to both push people toward shared modes while discouraging single occupancy vehicle use. Examples of this currently happening can be found across the country. For instance Seattle's Commute Trip Reduction (CTR) state law requires employers with over 100 employees to develop a TDM plan. The benefits of the TDM plan are observed through the shift to non-SOV travel. From 2010 to 2016, downtown Seattle added 45,000 jobs, yet 95% of the net gain in commute trips used modes other than SOVs. These benefits could not have taken place if they were not coupled with supporting public policy. These policies include, among other things, land-use regulation to encourage pedestrian-oriented infrastructure, micromobility parking standards, mobility hubs to centralize access to transportation, increase in transit frequency and service, and strong public-private partnerships. Additional TDM and mobility-on-demand resources can be found in the Shared-Use Mobility Center's MOD Learning Center.

The recent surge in last-mile freight delivery presents additional opportunities outside the current scope of this tool. These opportunities include crowd shipping, centralized pick-up/drop-off locations, cargo bikes for urban delivery networks, and technology solutions toward consolidating deliveries. However, the methods described in this calculator do not include freight. Instead, this tool is designed to show the impact of investments in personal transportation infrastructure, shared mobility technologies, and vehicle electrification. Supply chain improvements fall under freight transportation, which are currently not included in the CO_2 emissions analyzed here.

Using the Calculator

Fixed Setting:

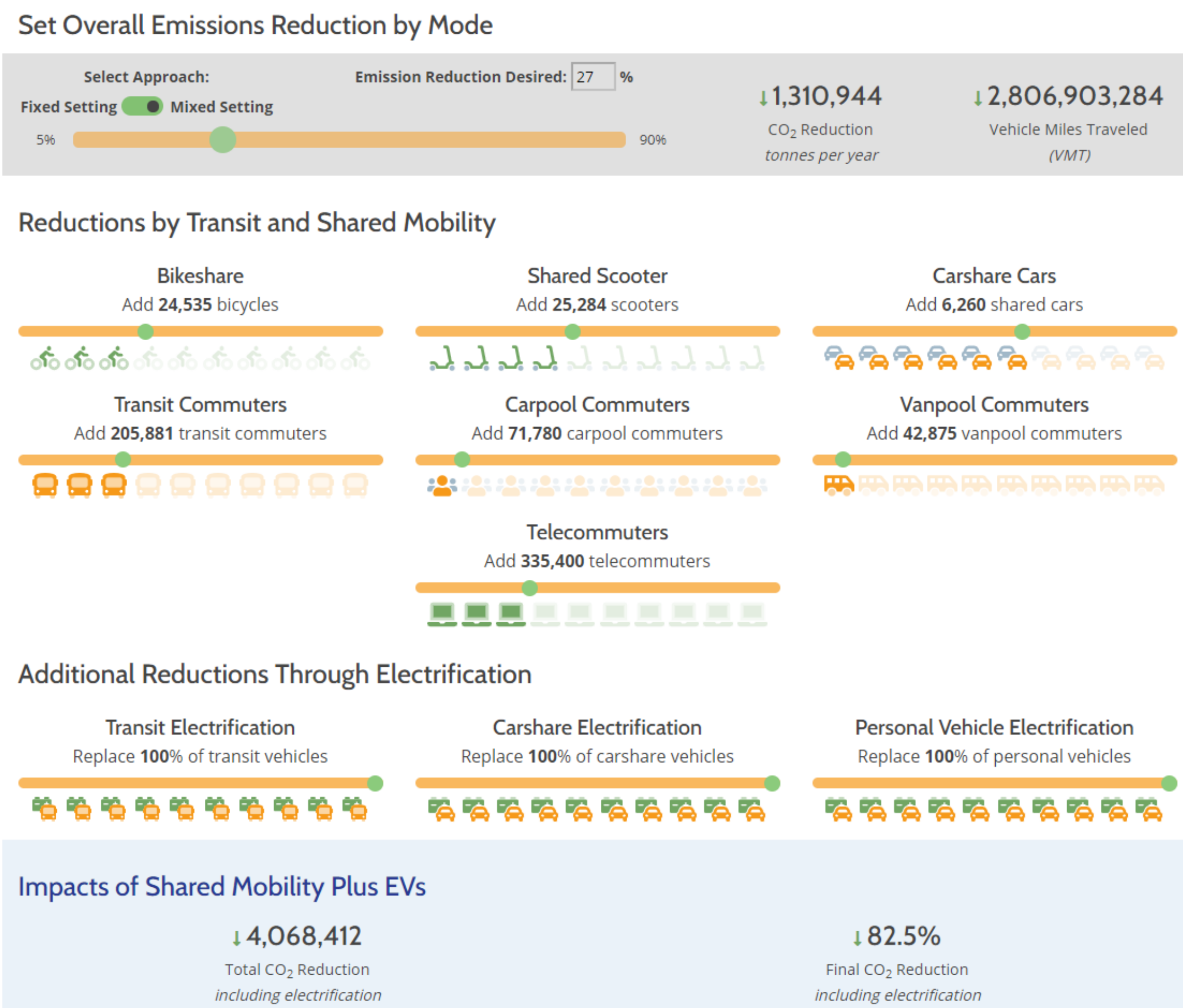


In "Fixed Setting", users input a desired emissions reduction as a fixed percentage of a city's current transportation emissions. The combination of modes is predetermined using the weights in Table 1. These weights represent the percentage of a city's overall emissions reduction actualized by each individual mode. These initial weights under the fixed setting are standardized across all of the cities and are designed to offer a starting point to look at the potential transportation related GHG savings. Transit takes up the majority of these contributions due to the scalability and proven resilience of the mode. Although the vehicle reduction capabilities of carshare have proven to be more modest than initially thought, even the matured expectations show that carshare has strong potential for VMT and GHG reduction. The literature tells us that scooters and bikeshare have a lower nominal impact on emissions than transit, carshare, and carpool, so that is why their combined weight is only 1.5% of the fixed model. However, it is important to note that this translates to tens of thousands of new scooters and bikes which add beneficial first- and last-mile versatility to any transit network.

Table 1: Each Mode's Contribution Towards Total GHG Reduction

Mode	**Weights**
Bikeshare	1.00%
Scooters	0.50%
Carshare	15.00%
Telecommuting	35.00%
Transit Commuters	35.00%
Carpool Commuters	10.00%
Vanpool Commuters	3.50%
Sum	100.00%

Mixed Setting:



In “Mixed Setting,” a city’s total emissions reduction is the final output while the user inputs become the individual modes.

Because the graphic user interface involves slider inputs, each mode in the Calculator has its own upper threshold. For commuter-based modes, these thresholds are based on the total current number of commuters in a city. This means that telecommuting, transit, carpool, and vanpool are all pulling from the same group of commuters. This number has a set limit based on ACS Census data. Telecommuting is prioritized due to COVID-19 and the large number of people currently working from home. Transit has a similarly high impact, but that comes with a higher capital investment so it has the second priority among these modes. Carpool and vanpool have lower impact coefficients and therefore see a lower priority in the calculator’s Mixed Setting. If raising one of these four sliders (telecommuting, transit, carpool, and vanpool) causes one or more of the other sliders to fall, this means the user has reached the maximum number of commuters.

Upper thresholds for bikeshare, scooters, and carshare are aspirational figures with some basis in real-world fleet sizes. The limit for new carshare units is based on double the per capita fleet size of car2go's network in Vancouver, BC, Canada before car2go permanently ceased operations. Even after car2go pulled its vehicles from Vancouver, the city maintained a very high number of active carshare users through the member-owned operator Modo (this is partly due Vancouver's reluctance as a city to allow TNC operation until recently). The threshold for scooters is based on the total scooters per capita in Santa Monica, California. As the birthplace of multiple scooter sharing operators (such as Bird and Lime), Santa Monica has a high rate of scooters per resident. The bikeshare threshold is based on Seattle's per capita fleet size following their efforts to manage a dockless program. An additional 20% is added to maximize the output of the calculator's estimates. For all modes, these limits are aspirational and not intended to function as maximum goals. Instead, the high thresholds are intended to preserve a variety of options for users while still allowing for slider bars in the user interface.

Electrification is handled secondarily for both Fixed and Mixed Settings. For the case of personal vehicles, the model first needs to determine how many vehicles are left over following the implementation of a multi-modal shared network. The VMT reductions brought by new shared modes have the assumed co-benefit of vehicle reductions, where the ratio of VMT/vehicle is different by city. The Center for Neighborhood Technology's H+T Index is used to measure the baseline VMT and transportation related GHG emissions at the city level. To calculate the impact of electrification, the user chooses a percentage of vehicles to electrify from each mode. For personal vehicles, that percentage is multiplied by the remaining vehicles. The impact of each car is determined by the difference of one gasoline vehicle's emissions compared with the emissions from the electricity generated to drive the same VMT in a standard electric vehicle.

Methodology:

The Shared Mobility Benefits Calculator includes US cities with more than 100,000 residents - or 312 cities in total (ACS 5-year estimates, 2012 - 2016). This methodology summarizes the sources used for reference to inform the coefficients of the Shared Mobility Benefits Calculator. The coefficients are the observed impacts that each of the modes have in terms of reducing GHG emissions. The Calculator itself is a linear regression model where the overall impact is the dependent variable and the explanatory variables are the number of added shared mobility units, such as new transit commuters or individual shared electric scooters. The coefficients assigned to each mode determine the impact of those new units. The references below are categorized by mode. These are followed by a discussion of the thresholds used, the incorporation of Electric Vehicles (EVs) to reduce GHG emissions, and the limitations surrounding the model.

Shared Mobility Modes

The shared mobility modes considered in this analysis are discussed below. Multiple studies were reviewed to identify the impact coefficients. For some modes, different approaches are evaluated to calculate the effect on transportation-related emissions (i.e. user surveys determining vehicle reductions compared with direct GHG analysis). This is not meant to be a comprehensive list of all available references regarding transportation's effect on climate. Instead, this document explains the methodology behind the Shared Mobility Benefits Calculator assumptions and analysis. The assumptions shown below were used to convert the unit of analysis to CO_2 reductions for studies based on Vehicle Miles Traveled (VMT) or vehicle reduction. It is also important to note that all of the explanatory variables used (commuters and shared vehicles) represent *new* units in addition to the resources already available in each city. Current units of transit and carpool commuters are factored into each city's existing carbon impact. However, due to data availability, existing shared mobility fleet sizes such as electric scooters and bikeshare bikes are not factored into the analysis.

Table 2: Summaries of the impact coefficients used in this analysis:

Shared Mode	**Coefficient** (tonnes of CO2 Reduction/Unit)	**Users/Units per car shed**
Public Transit Commuting	2.27	2.06 (new transit commuters per vehicle reduction)
Bikeshare	.41	11.6
Scootershare	.19	24.0
Carshare	6 (vehicles shed) x (local GHG/vehicle) GHG per vehicle varies by location	6
Carpool/Vanpool Commuting	1.04	4.48
Telecommuting	0.58 – 2.23 (determined by the city's average length of commute and current commuter mode split)	2.13 – 8.18

Data Sources:

The Shared Mobility Benefits Calculator uses a combination of Census Data through the American Community Survey (5-Year Estimates, 2012-2016) along with VMT and CO_2 emissions data modeled (at the city-level) by the Center for Neighborhood Technology through their Housing + Transportation (H+T) Index.

Table 3: Data Sources Used in Analysis

Name	Variable(s)	Source	How it is used
Demographic	Households, Population, Commute Mode Split, Aggregate Vehicles	American Community Survey, 5-Year Estimates, 2012-2016	Data used to identify current commute mode split and to estimate potential growth of shared mobility. Aggregate vehicles and household data used to describe current characteristics.
VMT and Transportation Emission Data	H+T data	Center for Neighborhood Technology H+T Index	City VMT and transportation emission baseline data.
eGRID Source Data	eGRID source data by subregion	EPA eGRID Summary Tables	Data used to calibrate the electric vehicle energy source data.
GHG Equivalent Benefits	Various benefits available through the EPA Calculator	EPA Greenhouse Gases Equivalencies Calculator	Used to estimate equivalent benefits to reduced VMT and transportation related GHG emissions.
Electric Bus Data	Average Bus Occupancy by UZA/State	FHWA Developing a Statistically Valid and Practical Method to Compute Bus and Truck Occupancy Data	Used to estimate bus occupancy when converting VMT emission rates to PMT equivalent rates
Commute Distances	Average Length of Commute (by Metro Area)	Brookings Institute: The Growing Distance Between People and Jobs in Metropolitan America	Used to estimate the GHG impact of shifting commuters to shared modes and away from single occupant vehicle trips

Summary of Reduction Coefficients

Bikeshare

By taking the average of the equivalent GHG figures found across these five studies and choosing the more conservative numbers where applicable, the final emissions savings (not differentiated by VMT reduction, CO_2 analysis, or ownership) is **0.4019 tonnes CO_2 saved annually per bike**. This coefficient is then used in the Shared Mobility Benefits Calculator to scale the potential impact of bike share networks in urban transportation systems across the country.

Equivalent Benefits via VMT Reduction

Table 4: VMT Reduction Bikeshare Studies

Study	VMT saved/bike	Vehicle Equivalent	GHG Savings
Fishman et al. (2014)	49 to 153	0.004 to 0.013 vehicles	**28.2 kg CO_2 per bike annually**
LDA Consulting (2016)	2,305	0.20 vehicles	**909 kg CO_2 per bike annually**

Fishman et al. (2014) and LDA Consulting (Capital Bikeshare) (2016) report VMT reduction due to bikeshare being present. Fishman et al. describes in table 2 of the article the vehicle kilometers traveled (VKT) savings per bike in cities in the United States, Australia, and the UK. The data are from 2012. With the numbers converted to miles, the results range from 49 to 153 VMT per bike. The Capital Bikeshare Member Survey Report completed by LDA Consulting in 2016 shows a total of 9.9 million VMT saved. The report does not explicitly state how many bikes are in the system so the 2018 number of 4,300 bikes was used. 2,305 VMT was saved per bike but the data are from Capital Bikeshare members whose average annual VMT is only 3,995 miles. In car equivalents of VMT, **the range in numbers found is 0.004 to 0.20 vehicles shed.** Using the EPA's aggregated figure of 4,543 kg CO_2 produced annually by the average vehicle (11,244 miles at 404g CO_2 per mile), the range in VMT savings converts to **28.2 to 909 kg CO_2 saved per bike annually.** The wide gap between these figures illustrates the need to include a broad range of studies across multiple methods.

Fishman, E., Washington, S., Haworth, N. (2014). Bike share's impact on care use: Evidence from the United States, Great Britain, and Australia. Transportation Research Part D. p13-20.
http://mobility-workspace.eu/wp-content/uploads/Bike-shares-impact-on-car-use-3.pdf

LDA Consulting (2016). 2016 Capital Bikeshare Member Survey Report.
https://d21xlh2maitm24.cloudfront.net/wdc/Capital-Bikeshare-SurveyReport-Final.pdf?mtime=20161206135935

Car Equivalents via CO_2 reduction

Table 5: CO_2 Reduction Bikeshare Studies

Study	GHG Saved	GHG annual savings per bike
Shaheen et al. (2014)	38,575 to 280,339 total kg CO_2 saved per year per system	**391 kg CO_2**

Shaheen et al. (2014) determined CO2 savings in several cities in the U.S (the study includes cities in China but those were not included here). The data are from 2011. The number of bikes in 2011 are 270 in Madison (compared to 40,805 kg CO_2 reduced), 110 in Boulder (47,174 kg CO_2), 140 in San Antonio (38,575 kg CO_2), and 520 in Denver (280,339 kg CO_2). After summing all the CO2 reduced and summing the total bikes, **the average CO_2 saved annually across these cities per bike is 391 kg CO_2 per bike.**

Shaheen, S., Martin, E., Nelson, C., Cohen, A., Pogodzinski, M. (2014). Public Bikesharing in North America during a Period of Rapid Expansion: Understanding Business Models, Industry Trends, and User Impacts. Mineta Transportation Institute.
https://transweb.sjsu.edu/sites/default/files/1131-public-bikesharing-business-models-trends-impacts.pdf

Surveyed Car Ownership Reduction

Table 6: Car Reduction Bikeshare Studies

Study	Ownership Reduction	GHG Saved
LDA Consulting in 2011 (2012)	0.10 vehicles	**0.4543 tCO_2**
Shaheen and Martin (2015)	0.05 vehicles	**0.2272 tCO_2**

In their 2011 member survey, Capital Bikeshare asked members who owned a car at the beginning of their membership (n = 2,996) if they sold their vehicle. Three options were given. They answered either “No,” “considered selling/donating vehicle”, or “sold/donated vehicle.”

Ten percent of these members said they considered shedding a vehicle and an additional five percent actually did. **If all 10 percent that said they "considered selling/donating" *did* sell their car in addition to the 5 percent who went through with it, a total of 450 cars were sold, or 0.3 cars shed per bike. If only the 5 percent sold their car, then each bike only reduces 0.1.** For the purpose of the Shared Mobility Benefits Calculator, we are considering the users who actually went through with selling/donating their vehicle, which converts to 0.4543 tCO_2 saved per bike. A broader study by Shaheen and Martin in 2015 found that each bike is equivalent to half the vehicle reduction figure found by the Capital Bikeshare study -- this follows a standard trend where earlier studies capture the most enthusiastic users willing to sell their cars and later studies produce more modest figures of vehicle reduction.

LDA Consulting (2012). Capital Bikeshare 2011 Member Survey Report.
https://d21xlh2maitm24.cloudfront.net/wdc/Capital-Bikeshare-SurveyReport-Final.pdf?mtime=20161206135935

Shaheen, S., Martin, E. (2015). Unraveling the Modal Impacts of Bikesharing. Access Magazine number 47.
https://www.accessmagazine.org/wp-content/uploads/sites/7/2015/12/access47.shaheen.pdf

Scooters

The reduction of GHG emissions used in this analysis is 0.195 tCO2 per scooter. Because scooters are the most recent mode included in the calculator, there is very little research on their impact. Aside from operator-published studies or life cycle analyses of scooter production (which were not considered because life cycle did not factor into our analysis of bike share, transit, or auto-based modes), one of the available impact studies came from the Milwaukee Department of Public Works. From August to November of 2019, Milwaukee collected data from 348,190 scooter trips from 1,350 permitted devices across three private operators throughout the city. For the purpose of the Calculator, trips were assumed to have an average length of 1.25 miles (which is consistent with other comparable scooter pilots). Through user surveys, the city found that 44% of scooter trips replaced a trip in an automobile (either in a single occupant vehicle or a TNC). Normalizing the program across a fully year to estimate annual impacts gives the following:

348,190 * 365/107 (days in a year/days in the pilot) * 1.25 (miles/trip) * 0.44 (percent trips replacing driving) * 0.000404 (tonnes CO2 per auto mile traveled) / 1350 scooters

= 0.195 tCO2 per scooter

Milwaukee's report summary can be found here:

https://city.milwaukee.gov/MilwaukeebyBike/Shared-Mobility1/Dockless-Scooter-Pilot-Study.htm#.XkQtIWhKhPZ

Carshare

According to a recent study by Shaheen et al (2020), carshare across the United States has declined since its peak in 2016. However, member growth has continued to rise, with over 1.4 million members in 2018, indicating that carshare remains an important mobility option. Based on recent studies, one-way carshare has been observed to remove an average of six personal occupancy vehicles off the road. A 2018 study by Namazu and Dowlatabadi provides a comprehensive literature review in their study. Many of the numbers presented here are from Table 1 of their study. Other important outcomes from the Namazu article is the differentiation between the ownership effects of one-way and two-way carsharing. One-way carsharing is about complementing the users' mobility options while two-way carsharing showed more potential for realized personal vehicle ownership reduction. The numbers presented in the table below are shown as the conservative/optimistic number. They are all based on personal vehicle ownership.

Table 7: Carshare Vehicle Reduction Coefficients (from Namazu & Dowlatabadi, 2018)

Study	One-way	Two-way
Namazu and Dowlatabadi (2018)	6	5
Steer Davies Gleave (UK context) (2015a) via Namazu table		4/13
Steer Davies Gleave (UK context) (2015b) via Namazu table		8.6/28.4
Steer Davies Gleave (UK context) (2015c) via Namazu table		3.9/12.8
Stasko et al. (2013) via Namazu Table		15.3
Martin et al. (2010)	9/13	
Martin and Shaheen (2016)	1-3/7-11	
TCRP 108 (2004)		5
Cervero and Tsai 2004		6.76
Firnkorn and Muller (2012)	0.44/1.08	

Namazu and Dowlatabadi (2018) provides a table that summarizes what has been found. All these studies surveyed carsharing members where in all cases had lower average vehicle ownership per household than their comparable areas. Some of these references are based on carsharing services in the UK but are still helpful. These are all based on ownership. **The average vehicle reduction per carshare vehicle (with no differentiation between one-way or two-way) is 6 when only conservative numbers are used, following the approach from the bikeshare studies.** This number is then multiplied by the average CO_2 emissions per vehicle, which varies by city. This variation is due to the local difference in household VMT modeled through the Center for Neighborhood Technology's H+T Index -- for example, a vehicle in New York City is expected to see far fewer annual miles than a vehicle in Dayton, Ohio. Thus, the average emissions impact of a carshare vehicle varies to the same degree.

Namazu, M., Dowlatabadi, H. (2018). Vehicle ownership reduction: A comparison of one-way and two-way carsharing systems. Transport Policy volume 64. https://ideas.repec.org/a/eee/trapol/v64y2018icp38-50.html

Transit, Carpool, Vanpool

Table 8: Transit and Carpool/Vanpool Reduction studies

Study (mode)	**Stated Number**	**Convert to GHG**
USDOT FTA 2010 **(Transit)**	0.96 lbs CO_2 per passenger-mile in personal vehicle vs 0.45 lbs CO_2 per passenger-mile in transit or (0.96-0.45)/0.96 for vehicle equivalent	**2271.5 kg CO_2 annual net savings per person**
Minett and Pearce 2011 **(Carpool, also used for Vanpool)**	"200-400 litres of fuel saved per slugging carpooler in SF" (52.8 to 106 gallons)	**1,044.9 kg CO_2 annual net savings per new carpool or vanpool commuter**

The numbers from the FTA paper are based on pounds of CO_2 per passenger mile. VMT is the underlying variable with passenger-equivalents found through transit occupancy rates, which the study averages across the largest transit systems in the US. While such a coarse approximation lacks nuance by nature, it gives us a set of underlying assumptions to scale the effects of transit across multiple modes (bus, rail) and all US cities with more than 100,000 residents. The carpool/vanpool coefficient was obtained from a 2011 study by Minett and Pearce (2011) in which they report gallons of fuel saved by casual carpooling in the San Francisco Bay Area. Since the CO_2 emissions figure is based on fuel burned, this number can be used interchangeably with CO_2 emissions.

USDOT 2010. Public Transportation's Role in Responding to Climate Change.
https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/PublicTransportationsRoleInRespondingToClimateChange2010.pdf

Minett, P., Pearce, J. (2011). Estimating the Energy Consumption Impact of Casual Carpooling. Energies.
https://www.mdpi.com/1996-1073/4/1/126/htm

Telecommuting

The impact of a single commuter switching to telecommuting is based on their commute distance, their current commuting mode, and how many days they commute. A 2015 study by the Brookings Institute used the Census Bureau's Longitudinal Employer-Household Dynamics Survey to analyze commute distances in the top 96 Metros in the US. Metro areas within Massachusetts were missing from the study due to lack of data. Those values were interpolated based on the number of commuters in every other metro area. For cities within the SUMC calculator that fell outside the metros in the Brookings study, an average commute distance was used.

In attempting to account for a city's current commuting mode split, the relevant ACS data were incorporated into the model for each city. For example, Chicago has ~50% SOV, 28% transit, 13% walking + biking + telecommuting, and 8% carpool/vanpool. For the sake of simplicity, the calculator makes several assumptions. First, biking, walking, and telecommuting have no impact on GHGs. Furthermore, carpool/vanpool commuters are assigned half as many emissions per as SOVs, and transit commuters are assigned 1/4th the emissions of an SOV commuter. The lack of detail affords this tool scalability when looking at hundreds of separate cities with unique transit systems.

The calculator further assumes that every commuter works 240 days, uses the same mode every day, and has an average-length, roundtrip commute compared to their home city. The product is a total "commute mile" savings, which is then multiplied by the mode split and the rate of CO_2 per VMT. The final equation is below:

(*One-way commute distance****)*** *x* ***(****2 trips per day****)*** *x* ***(****240 commuting days per year****)*** *x*
(*%SOV + 0.5 * %Pool + 0.25 * %Transit****)*** *x* ***(****404 g* CO_2 *per VMT****)***

Electrification

One way the Shared Mobility Benefits Calculator demonstrates the location-based elasticity of emissions generation is in the value of a single car. For example, the average modeled car in Cleveland, Ohio is driven for many more miles per year than the average car in New York City. A car with more annual vehicle miles traveled, or VMT will generate more carbon emissions proportional to the increase in distance traveled, and thus emissions from the transportation systems in New York City and Cleveland will look quite differently even before including cleaner modes like bikeshare or transit. When replacing six personal cars for every one new carshare vehicle, the six cars replaced will have a different impact depending on the city they're being driven in.

Similarly, all electrified modes operate differently by city. The primary source of data to measure these differences comes from the EPA's Emission Generation Resource Integrated Database, or eGRID. This source splits the United States (including Alaska and Hawaii) into 26 distinct subregions, each with their own distinct emissions rates for multiple pollutants. For the purpose of the Shared Mobility Benefits Calculator, only CO_2 emission rates were considered.

When electrifying any form of transportation, it is important to understand the source of energy generation to better comprehend the carbon emissions created from travel. To that end, all 312 cities in the Calculator were matched with their appropriate eGRID subregion.

eGRID shapefiles:

https://www.epa.gov/energy/download-egrid2016-shapefiles

EV Carsharing

According to monthly and yearly sales data at insideevs.com, the best-selling electric vehicle in 2019 (with more than 750% of the sales of the next best-selling EV) is the Tesla model 3. According to fueleconomy.gov, six different variants of the Tesla Model 3 have an average efficiency of **27.0 kWh per 100 miles**. The Model 3 is more efficient than most other battery electric vehicles sold (Nissan Leaf = 30, Chevy Bolt = 28, Tesla Model S = 34), so this estimate represents an optimistic outlook for an electric carsharing system.

Emissions from each sub region of the electric grid come from the EPA's Emissions & Generation Resource Integrated Database (eGRID). Shapefiles provided by the EPA were used to match cities in the calculator with the appropriate eGRID subregions and their corresponding CO_2 emissions factors. The EPA provides these factors in lb CO_2/MWh which were converted to metric tonnes CO_2/kWh (multiply by 0.0004536 and then divide by 1000).

The same ratio of vehicle reductions from standard car share (6 personal vehicles removed for every new carshare vehicle) were used to calculate VMT and then CO_2 reductions.

Inside EVs Sales Data:

https://insideevs.com/news/357565/ev-sales-scorecard-june-2019/

Fuel Economy figures:
https://www.fueleconomy.gov/feg/PowerSearch.do?action=noform&path=1&year1=2019&year2=2020&vtype=Electric&sortBy=Make&rowLimit=200&tabView=0&pageno=1

EV Transit (Bus Electrification)

The clean-air benefits of electrification are most fully-realized when combined with shared mobility, and no transportation mode shares more efficiently than transit. Unfortunately, most current transit buses in operation run on diesel fuel. Despite a reputation for reliability, diesel engines have a relatively high emission rate.

The Calculator only considers the effects of electrifying bus transportation for this section. Most inner-city rail transit is already electrified in the United States, while most bus transportation is not. With regard to bus electrification, a report by the Union of Concerned Scientists extrapolated on the EPA numbers (along with figures of 4.8 miles per gallon in a diesel bus and 2.02 kWh per mile in an electric bus) to determine the individual mpg improvements of an electric bus in all 26 eGRID subregions. These improvements ranged from a 37.3 mpg difference in Upstate New York (where hydroelectric and nuclear power are the two largest sources of energy) to 2 mpg improvement on the island of Oahu, where 70% of energy is directly converted from crude oil. According to the EPA's Emission Factors for Greenhouse Gas Inventories, one gallon of diesel fuel is worth 10.16 kg CO_2. Using the 4.8 mpg figure for the average bus, one diesel bus VMT produces 0.00212 tonnes CO_2. Employing the same conversion for the regional EV bus equivalence estimates, the emission reductions per EV bus mile ranged from 0.00062 tCO_2 in Oahu to 0.00184 tCO_2 in Upstate New York.

Another transit characteristic that varies by region is the average occupancy of a bus. In their 2019 paper "Developing a Statistically Valid and Practical Method to Compute Bus and Truck Occupancy Data," the US Federal Highway Administration modeled average vehicle occupancies, producing figures at the Urbanized Area (UZA)-level and the state-level. These data were matched with the 312 cities used in the calculator, where state-level values were used for cities outside the UZAs included in the FHWA study. For every city, the average emission rate improvement (tCO_2 per VMT) was divided by the average vehicle occupancy, producing tCO_2 per PMT.

It is important to note that we are only considering the effects of bus electrification, as opposed to other transit modes such as light rail or subway. Many of these modes are already electrified. The American Community Survey monitors commute mode splits which highlights the regional differences in transit infrastructure. For example, less than 20% of the transit commuters in New York City take the bus to work. However, 98.5% of transit commuters in Milwaukee ride the bus. For the purpose of the Shared Mobility Benefits Calculator, the city's current ratio of bus commuters to all transit commuters is assumed to stay consistent as the model converts more SOV commuters to transit. The number of current bus commuters is added to the new bus commuters (bus/transit ratio multiplied by new transit commuters) to produce a total number of bus commuters.

The average commute distance of every studied Metro Area, or 7.7 miles (15.4 miles roundtrip) was used with all cities for transit electrification. The total number of bus commuters by city is multiplied by the city's reduction rate of bus emissions (in tCO_2 per PMT), the average roundtrip commute distance (15.4 miles), and 240 working days. The user controls the % of bus PMT to convert to electric, and the result is added to the model's total CO_2 reduction.

EPA Emission Factors for Greenhouse Gas Inventories (Table 2, Mobile Combustion CO_2 Emission Factors): https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf#page=5

O'Dea, Jimmy. "Electric vs. Diesel vs. Natural Gas: Which Bus is Best for the Climate?" Union of Concerned Scientists. July 2018. https://blog.ucsusa.org/jimmy-odea/electric-vs-diesel-vs-natural-gas-which-bus-is-best-for-the-climate

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Personal EVs

In order to convert a percentage of the remaining personal vehicles to electric, the number of "remaining personal vehicles" must first be estimated. In each city, a vehicle is worth a slightly different amount. Using the above example of Cleveland and New York, the average household in Cleveland has 1.17 vehicles (according to the ACS) and each household travels around 13,500 miles (according to CNT's H+T Index). Comparatively, New York City households have an average of 0.63 vehicles and travel an average of 8,300 miles. All that is to say "1 vehicle shed" is not a consistent unit of measurement when dealing with VMT or GHG reduction. However, those two data points (vehicles per household, VMT per household) can be used to estimate the impact of one vehicle by location. When aggregating all the emissions impacts of shared mobility – from converting SOV commuters to adding new services like bikeshare and scooters – the total emission or VMT reduction can be expressed as a number of vehicles' worth of emissions offset. This model assumes all cities have a current market of 2% EVs.

For the purpose of vehicle electrification, the Shared Mobility Benefits Calculator subtracts the equivalent vehicles from a city's current number of vehicles available (ACS). For the remaining pool of vehicles, the user defines a percentage to electrify. As with the other electric modes, the EPA's eGRID subregion defines a city's carbon emission rate for electricity generation. This model assumes the subregion's base load rate applies for all new vehicles.

Using the same methodology as EV Carsharing, each new EV was assumed to have an average efficiency of 27.0 kWh per 100 miles, so the emission rate can be expressed as tonnes CO_2 per EV mile. The impact of one personal EV conversion is defined as that city's eGRID emission rate (in tCO_2 per EV mile) multiplied by the average VMT of a car from that city. That number is then subtracted from the average GHG produced by one gasoline vehicle (defined as a city's entire transportation GHG inventory divided by the total number of vehicles available). This difference represents the individual impact of an electric vehicle for that city.

The user selects the percent of a city's remaining vehicles to be converted to electric. A 2% electric market share is assumed for each city. To that end, the user's input is multiplied by 0.98 and then multiplied by the number of "remaining" vehicles, then multiplied by the impact of an individual EV for that city. The result is an additional reduction in CO_2 emissions generated by converting private vehicles to EVs.

EPA eGRID Map:
https://www.epa.gov/energy/egrid-subregion-representational-map

EPA eGRID Tables:
https://www.epa.gov/sites/production/files/2020-01/documents/egrid2018_summary_tables.pdf

Limitations

There are several limitations noted in this analysis. First, the shared mobility benefits identified through research are applied to each mode but the analysis does not consider whether or not those same benefits are obtained by the same user across modes. A new bikeshare system, for example may appeal more specifically to existing transit and carshare users, even though the VMT reduction from the same users has already been "counted" towards a goal.

Second, the analysis is a linear regression, assuming benefits from the growth of shared mobility do not change with scale. The Calculator assumes the 3rd carshare vehicle in a system has an equal benefit to the 300th vehicle, and it assumes the same for all other modes. Invariably, the real world impact is not linear, and when the market reaches a certain level of saturation, the impacts could either decline or increase. Conservatively, the impacts of additional new modes could decline if the market has reached its capacity and the mobility needs of its users are fully met. More optimistically, the combination of modes could produce a greater impact in terms of changing travel behavior and reducing transportation-related greenhouse gases. For example, when shared mobility becomes widespread throughout a city and access is seamless, the increased visibility serves as an appealing advertisement to those who would otherwise not consider these modes. The same is true for shared infrastructure like bike lanes, bus lanes, and rail transit. This gap in knowledge shows the need for deeper research. Considering the rapidly changing market of shared mobility, this research would hopefully provide valuable reference for future tools.

It is also important to note the limitations of this model's view on Electrification. Every EV presented in this model, whether it be a bus or a shared car or a personal vehicle is assumed to use that region's "base load" equivalent grid emissions rate when charging. However, if every vehicle in a city suddenly needed to draw energy from the grid, the grid would need to compensate with extra capacity. Adding additional capacity (especially in a short time does not necessarily translate to cleaner electricity), but for the sake of our model, the base load rates in all eGRID subregions was assumed to be consistent following any major EV conversion.

Conclusions

The Shared Mobility Benefits Calculator should be viewed as a tool to help visualize the impacts of shared mobility in your community by reducing its transportation-related GHG emissions when it is brought to scale. However, unless these new modes are coupled with supportive land-use and transportation policies to encourage shared mobility and discourage travel through single occupancy vehicles - shared mobility will not reach its full potential. In this sense, the calculator is largely an aspirational tool. The impacts derived from each shared mode are based on real studies, but the subtext of each mode is the question of land use, willingness to promote non-SOV mode share, and location efficiency. Among the related considerations are a city's walkability, the necessary micromobility infrastructure (including bike lanes and sidewalks), a robust public transit system, and the spatial mix of population and employment density. By leveraging these fundamentals and applying the tools listed in the Shared Mobility Benefits Calculator, cities have the opportunity to use shared mobility and electrification to drastically reduce their transportation carbon footprint.